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Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

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As a PhD-fellow at the Technical University of Denmark (DTU), I focused on modelling uptake of pollutants to plants and how plants can be utilized to remediate contaminated soil- and groundwater. As our engineering classes at DTU have continuously increased in size, I recently moved into educational research as a postdoc.

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Professor Bazylak brings his engineering, education, and design experience to his role at the University of Toronto. His primary role is coordinating and teaching an award winning first year design and communications course (Engineering Strategies and Practice). As well he conducts action-based research into improving the learning experience of undergraduate engineering students and increasing diversity in the profession, particularly women and Indigenous peoples (Native Americans).

Professor Bazylak started his career as a manufacturing engineer in a new product introduction division of a large telecommunication manufacturer. He returned to academia joining the University of Victoria first as an engineering co-operative education coordinator and then as an engineer-in-residence. He joined the University of Toronto as a teaching focused professor where he is heavily involved in design education and diversity studies.

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Comparative Analysis of Two Teaching Methods for Large Classes

(Research paper)

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Abstract

Background Studying engineering has never been more popular and the societal need for engineering skills is immense. As a consequence, we are accepting more students into many of our programs.

Purpose To identify criteria for good practices within large class teaching and to evaluate two selected large class teaching methods (TMs) namely Active Learning Exercises (ALEx) and Team-Based Learning (TBL), against these criteria.

Design/Method First, the criteria for good teaching were identified via a literature review and include promoting active learning and meeting diverse ways of learning. Students and instructors involved in two different courses at Nanyang Technical University Singapore (NTU Singapore) and University of Toronto (UT), each representing a distinct TM, were subsequently surveyed. In the survey, students and instructors were asked to validate how important they found each of the identified criteria for good teaching. They were also asked to evaluate how well the respective TM supports each of these criteria for good teaching.

Results and Conclusions The criteria identified via the literature review were considered to be "important" to "very important" by both students and instructors at both universities. TBL performs markedly better than ALEx in this study when it comes to the facilitation of the good teaching criteria, although a direct comparison is difficult as teacher, student and context specific issues are not analogous. In order to validate and further explore the findings of this study, a follow-up research should be completed on a single group of students being taught the same course topic by a single group of teachers using different types of TMs. This would ensure direct comparison between the selected TMs and eliminate potential biases related to differences culture, age of students, course topics taught and teachers individual teaching skills.

Keywords: large class teaching; team-based learning (TBL); active learning exercises (ALEx); best teaching practices

Introduction

Studying engineering has never been more popular and the societal need for engineering skills is immense. As a consequence, we are accepting more students into many of our programs and our classes have become larger and larger over the years. Large classes are defined in this study as classes of more than 70 students and up to a 1000 students. Teaching large classes poses a series of challenges that may hamper learning in general, especially that of high-skilled students, and hence these are important to address. These challenges include decreasing teacher-to-student dialogue, promoting student disengagement and erosion of sense of responsibility for learning [1], [2].

As noted by Ramsden in 2003 [3], "many lecturers in the 1980s which handled classes of 30 to 50 students, are now faced with groups in the hundreds. Widening participation means that today's academics are also expected to deal with an unprecedentedly broad spectrum of student ability and background. They can no longer rely on students having detailed previous knowledge, especially in mathematics and science."

More recently, Graham [4] identified delivering student-centered learning for large classes as one of the key future challenges in engineering education. However, little research has so far been performed with regard to what constitutes "good teaching" when it comes to large classes and little work has been done with regard to evaluating existing and innovative teaching methods (TM) when it comes to address the challenges that large classes pose.

In order to address these research needs, we first reviewed the literature on what constitutes good teaching and reflect upon identified criteria and their feasibility when it comes to large classes. Second, we identified Team-based learning (TBL) and active learning exercises (ALEx) as two teaching methods, which have been proposed in the literature as alternatives to conventional teaching [5],[6]. Furthermore, these innovative TMs may have potential for widespread implementation in university teaching. Third, we analyzed and evaluated the two identified TMs against the identified criteria for good teaching of large classes and we discuss the limitations of our study and how the pros of both methods can, in theory, be used to optimize student learning. Finally, we provide a number of recommendations on how our findings can be further explored and validated. The research questions sought answered in this study are:

1) How important do students and teachers/instructors taught/teaching by TBL and ALEx find the identified criteria for large class teaching to be?
2) How well do TBL and ALEx support the identified criteria for large class teaching?

Criteria for Good Teaching

Putting forward criteria for what constitutes good teaching is challenging and arguably context, teacher and student dependent. Chickering and Gamson [7] and Ramsden [3] identified seven and thirteen criteria/properties, respectively, of good teaching.

Table 1. Criteria and important properties of "good teaching" identified by Chickering and Gamson [7] and Ramsden [3].

Criteria of "good teaching" identified by Chikering and Gamson [7]
1. Encourage contact between students and faculty to keep students motivated and involved.
2. Develop reciprocity and cooperation among students to sharpen the students' cognitive processes and promoted deeper learning.
3. Promote active learning as passive students do not learn as effectively as active ones.
4. Provide prompt feedback as formative and summative feedback is key to support ongoing student learning.
5. Emphasis time on tasks in order to develop the time-management skills of the students.
6. Communicate high expectations to motivate the students to expend an extra effort to meet these expectations.
7. Respect diverse talents and ways of learning and acknowledge that all student are unique and requires a variety of learning experiences to facilitate their learning.
Important properties of "good teaching" by Ramsden [3]
1. A desire to share your love of the subject with students.
2. An ability to make the material being taught stimulating and interesting.
3. A facility for engaging with students at their level of understanding.
4. A capacity to explain the material plainly.
5. A commitment to making it absolutely clear what has to be understood at what level and why
6. Showing concern and respect for students.
7. A commitment to encouraging independence.
8. An ability to improvise and adapt to new demands.
9. Using teaching methods and academic tasks that require students to learn actively, responsibly and co-operatively.
10. Using valid assessment methods.
11. A focus on key concepts, and students misunderstandings of them, rather than covering the ground.
12. Giving the highest quality feedback on student work.
13. A desire to learn from students and other sources about the effects of teaching and how it can be improved.

Obviously, there is some overlap or alignment between the principles proposed by Chickering and Gamson and the properties put forward by Ramsden. For instance, Ramsden's "showing concern and respect for students" and "using TMs and academic tasks that require students to learn thoughtfully, responsibly, and cooperatively" are similar to Chickering and Gamson's "respects diverse talents and ways of learning" and "develop reciprocity and cooperation among students" [8]. The importance and relevance of many of the criteria put forward by Chickering and Gamson and Ramsden are independent of the size of a given class e.g. having a desire to share your love of the subject with students or communicating high expectations. *Table 2a* provides an overview of the seven criteria for good teaching identified in this study. The seven criteria address a series of didactic issues relevant for teaching in general and especially for large classes. However, they do not address issues related to resources, economy and the overall feasibility of the TMs. To account for this, three additional criteria were added, *Table 2b*, dealing with instructor and technical resources required and the flexibility with respect to facilities.

Table 2a. Criteria for good teaching practices in large classes independent of teaching form, the rationale behind including the criteria and the references for why the criteria are important to the comparison and evaluation of large class teaching.

Criteria	**Rationale for including criteria and references for why the criteria are important.**
1. Encourage contact between students and faculty.	- Student-faculty interactions within and out of classes promote student commitment and motivation [7], [9]. - Faculty members serve as inspiration and as partner of discussion improving the aspiration of the students [3], [7], [10]. - Learning requires cooperation between student and faculty. Enhanced student-faculty contact promotes the cooperation [11].
2. Promote student collaboration and responsibility for own learning.	- After graduation students will enter jobs where team-work-skills are often a requirement or at least appreciated [12]. - Collaboration promotes corporative learning [3], [13]. - Students learn from each other and learn from teaching each other [3], [14].
3. Promote active learning.	- Active learning is one of the major keystones assuring high academic gains [3], [7], [14-16].
4. Meet diverse ways of learning.	- Students do not learn the same way and they bring in different competences to learn. To meet these diverse ways of learning the educators must facilitate various styles of teaching so that all students have the opportunity to learn within their comfort zones but challenge themselves by learning in new ways [3], [7], [11].
5. Promote critical thinking.	- The literature is in consensus that the development of critical thinking is a vital skill for students. Students which master critical thinking have greater success in education and career and are of much more importance to society [3], [17].
6. Gives prompt feedback.	- Students need to know what they do not know in order to focus their learning [3], [7], [9].
7. Provide structure and guidance with respect time management.	- Structure helps students to recognize and improve deep learning [18]. - Students need help to learn effective time management [7].

Table 2b. Other criteria deemed important for the feasibility of the teaching methods

Criteria	**Rationale for including criteria**
a. Need for instructor resources.	With large classes, the TMs require a lot with respect to instructor time allocated per student e.g. feedback, grading of assignments. This criterion assesses the overall instructor workload.
b. Need for technical resources.	The technical feasibility of the TMs must be assessed. Does the approach require advanced technology? This criterion evaluates the economical investments required for the teaching approach to be feasible.
c. Flexibility with respect to facilities.	From an administrative point of view it is important to assess if the teaching approaches are tied to specific facilities. e.g. special class room features. This criterion assesses how likely it is to apply the teaching approach at any given location.

Teaching Methods

A range of different TMs have been proposed in the literature [19-23]. In our analysis we included ALEx and TBL which traditionally have been proposed as alternative to conventional teaching and which may have potential for widespread use in university teaching.

Team-based learning

TBL was developed at the University of Oklahoma in the late seventies to meet the challenge of increasing enrolment. It is an instructional method where the students, in small teams, apply conceptual knowledge following a three phased protocol [22]. Phase I is an individual pre-class study, where the students familiarize themselves with the knowledge needed for solving in-class challenges. Phase II is a readiness assurance test (RAT) consisting of an individual readiness assurance test (iRAT) and a team readiness assurance test (tRAT). First, the students complete the iRAT which typically is a multiple choice test. Then the students complete the tRAT by answering the same set of questions as a team while getting immediate feedback. Phase II ends with the facilitator bringing up issues identified by the RAT and the students can ask questions before the teams apply the knowledge gained in a decision-based exercise. Phase III is the application exercise where real and relevant, usually case-based problems are presented to the students. The students need to apply the concepts learned in the pre-class phase and validated by the RAT. Classical TBL holds seven core elements: 1) Team formation; 2) RATs; 3) Immediate feedback systems; 4) In-class team-based problem solving; 5) Application of the 4S-principle (**S**ignificant problem; At a given time working at the **S**ame problem; **S**pecific choice and **S**imultaneous report); 6) Structure; and 7) Peer review [24].

Active learning exercises

ALEx or active learning activities (ALA) is an instructional method where pre-planned activities in class make the students put to use the content that they have just been taught. Many different ALA and ALEx exist [23], [25], which are either informal or graded. The plainest version of ALEx is regular multiple choice questions, which the students have to solve during lectures but ALEx also comes as small written exercises, sketch drawings, group work activities or the like. In class, the instructor presents the theory or case(s) and instruct the students how to answer the upcoming ALEx. Typically, the ALEx activities open for student submissions only for a few minutes thus, when conducting graded ALEx, the students are forced to be present in class or risk missing points for the grading – misses the timeslot where submissions are accepted or miss important instructions. Typically, ALEx requires application of a learning management system (LMS) like Canvas, Top Hat, Kahoot or similar, in order to facilitate the student-faculty interaction, submission of answers and, if required, subsequent grading.

Methodology and Data Collection

For the comparative analysis students and instructors from Nanyang Technological University Singapore (NTU Singapore) and University of Toronto (UT) representing TBL and ALEx, respectively, completed a questionnaire survey. The survey was conducted in the fall semester of 2018. In the survey, they were asked to evaluate how important they found each of the criteria for good teaching identified in this study on a scale from 1 to 5, where 1 corresponds to “unimportant” and 5 to “Very important”. Similarly, they were asked to evaluate, on a scale from 1 to 5, how well the respective TM applied in their respective classes supports each of the criteria, where 1 corresponds to “Not at all” and 5 to “Very well”. Instructors were also asked to assess the additional three criteria considering the feasibility of the TM. Data has not been normalized and are presented as average scores of all survey responses.

Results

For NTU Singapore a first semester Renaissance Engineering Programme (REP) class in natural sciences of 55 students was surveyed. The response rate was 80%. In addition, 11 teachers, those active within the academic year, were surveyed with a 100% response rate. For UT, a first semester design class of 850 students and 50 teachers/TAs was surveyed. The response rates were 6% and 8% for students and teachers/TAs, respectively.

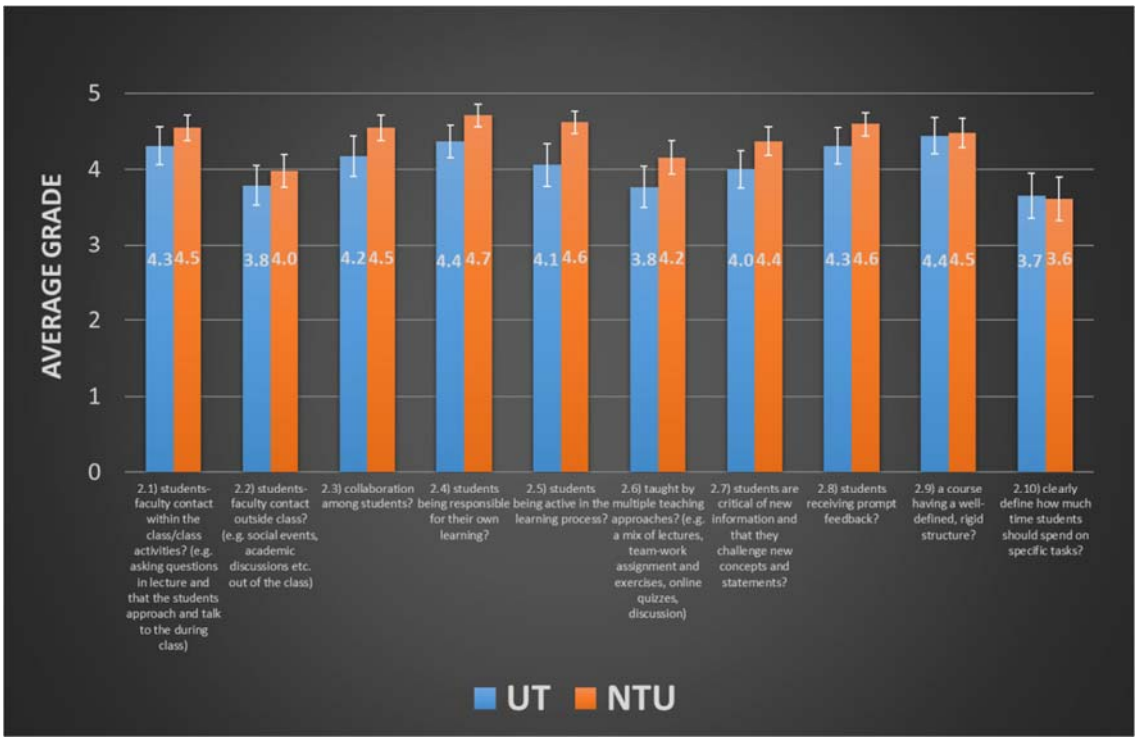

Figure 1. How important the students at University of Toronto and Nanyang Technological University found the identified criteria for large class teaching to be. Each criteria was evaluated on a scale from 1 to 5, where 1 corresponds to "Unimportant" and 5 to "Very important". Error bars indicate 95% confidence intervals.

The students perceived all the identified criteria to be in the range of important to very important, *Figure 1*. Only three of the criteria received average grades below four at UT and one criterion at NTU Singapore. None of the criteria scored an average grade of less than 3.6. The evaluations of the importance of the identified criteria are similar for both UT and NTU Singapore. Only for "students being active in the learning process", do the 95% confidence not overlap, with the students at NTU Singapore scoring the criteria significantly higher than those at UT (4.6±0.1 vs. 4.1±0.3). The criterion considered the most important is "students being responsible for their own learning" at both UT and NTU Singapore (4.4±0.2 at UT and 4.7±0.2 at NTU Singapore). At UT the criterion "a course having a well-defined, rigid structure" also received and average grade of 4.4±0.2. The criterion scoring the lowest average grade for both universities was "clearly define how much time students should spend on specific tasks", which received 3.7±0.3 and 3.6±0.3 for UT and NTU Singapore, respectively. The criterion "students being active in the learning process" had the highest difference in average grades (0.5) (*Figure 1*).

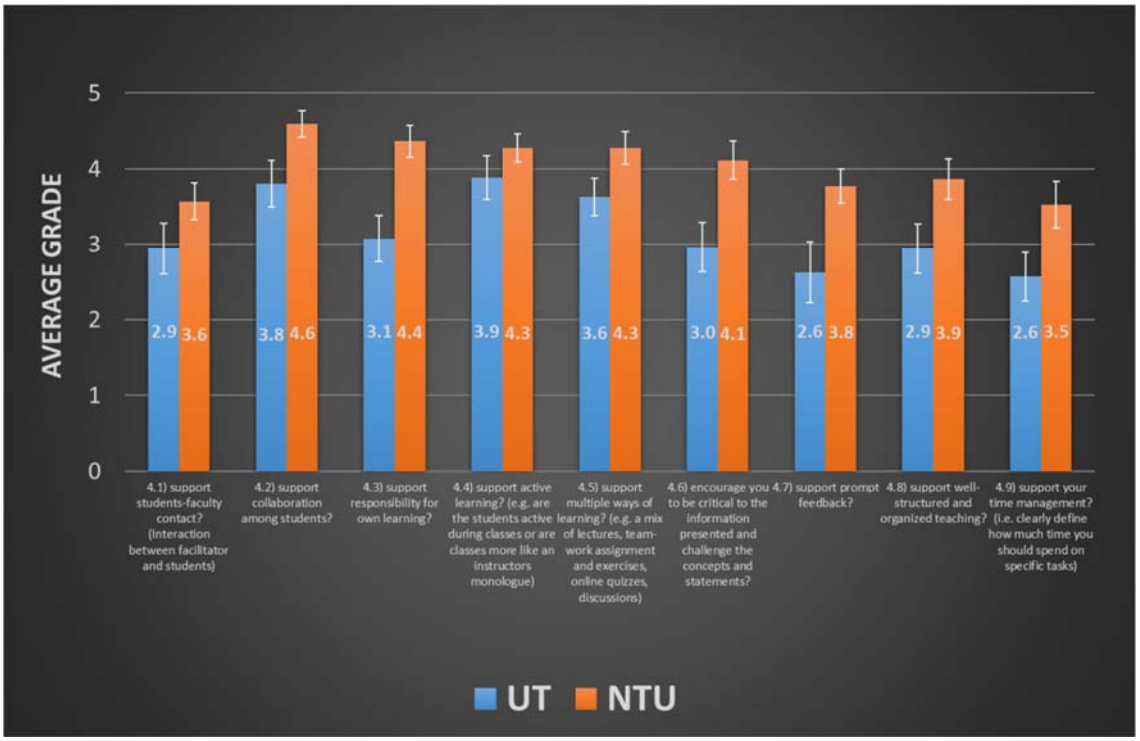

Figure 2. How well the students at University of Toronto and Nanyang Technological University found ALEx and TBL to support the identified criteria for large class teaching. Each criterion was evaluated on a scale from 1 to 5, where 1 corresponds to "Not at all" and 5 to "Very well". Error bars indicate 95% confidence intervals.

When it comes to how well ALEx and TBL, from the students perspective, support and facilitate the identified criteria, there are major differences, *Figure 2*. TBL is, for all parameters, scoring higher average grades compared to ALEx. For ALEx at UT the average scores are ranging from 2.6±0.4 to 3.9±0.3 with four criteria scoring below 3. The two criteria scoring the lowest grade for ALEx is "support prompt feedback" (2.6±0.4) and "support your time management" (2.6±0.3) and the criterion scoring the best average grade for is "support active learning" (3.9±0.3). For TBL at NTU Singapore the average grades are ranging between 3.5±0.3 and 4.6±0.2, with "support your time management" scoring the lowest and "support collaboration among students" score the highest. The largest difference in mean observed (1.3) is for the criterion "support responsibility for own learning" (*Figure 2*).

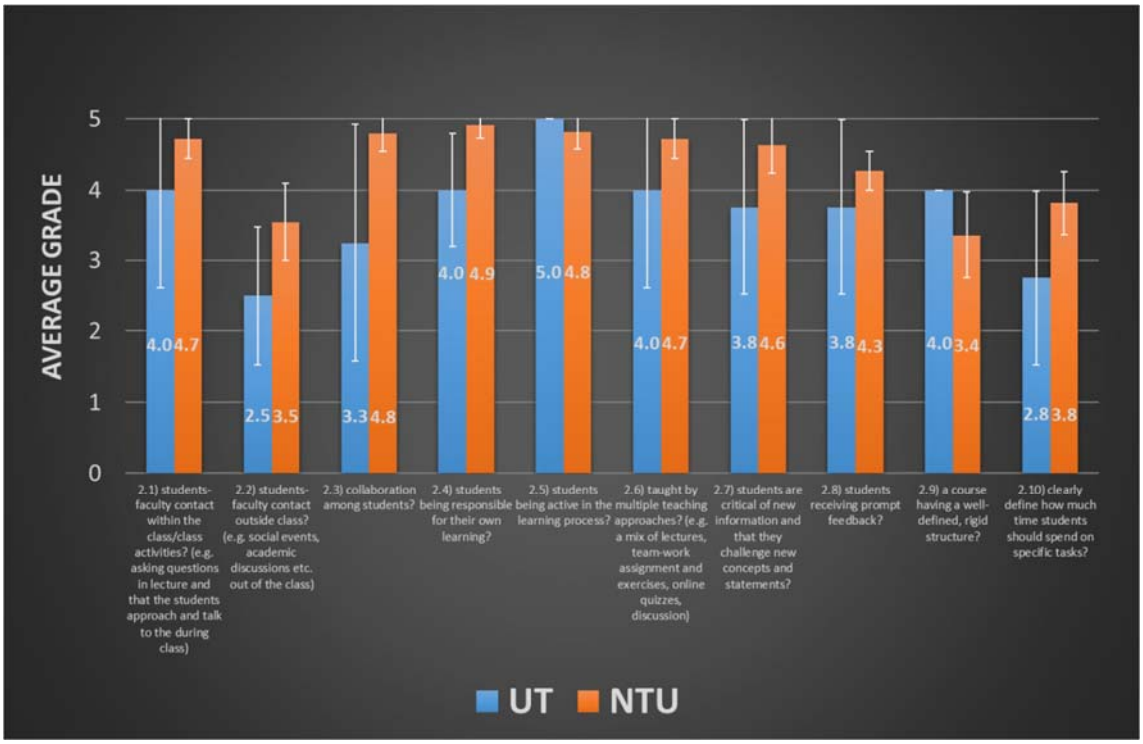

Figure 3. How important the teachers/TAs at University of Toronto and Nanyang Technological University found the identified criteria for large class teaching to be. Each criteria was evaluated on a scale from 1 to 5, where 1 corresponds to "Unimportant" and 5 to "Very important". Error bars indicate 95% confidence intervals.

Similar to the students, the instructors and TAs rated most of the identified criteria to be in the range from important to very important, *Figure 3*. However, the importance of "student-faculty contact outside classes" and "clearly define how much time students should spend on specific tasks" were both rated below average at UT. The criterion found to be the most important by the instructors was "students being active in the learning process" (5±0) at UT and "students being responsible for their own learning" (4.9±0.2) at NTU Singapore. Opposite, the least important criterion was "student-faculty contact outside classes" (2.5±1.0) at UT and "a course having a well-defined, rigid structure (3.4±0.6) at NTU Singapore. The larges difference in average grade obtained (1.5) is observed for the criterion "collaboration among students" (*Figure 3*).

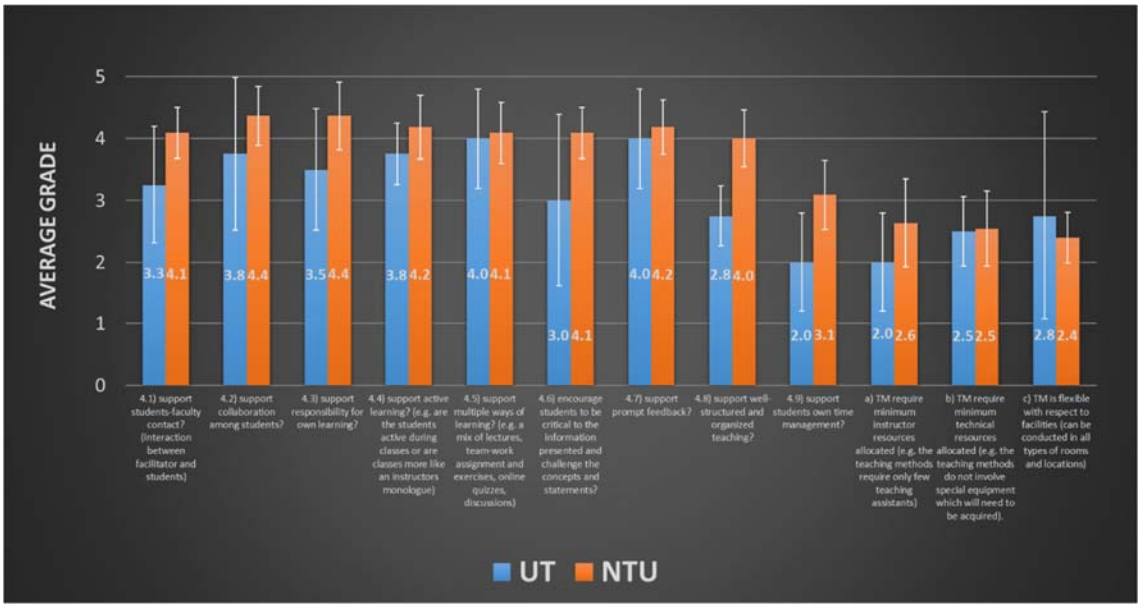

Figure 4. How well the teachers/TAs at University of Toronto and Nanyang Technological University found ALEx and TBL to support the identified criteria for large class teaching plus the three additional criteria addressing the feasibility of the teaching method (ALEx at UT and TBL at NTU Singapore). Each criterion was evaluated on a scale from 1 to 5, where 1 corresponds to "Not at all" and 5 to "Very well". Error bars indicate 95% confidence intervals.

Observing the teachers and TAs assessment of how well ALEx (at UT) and TBL (at NTU Singapore) support the identified criteria for large class teaching, the same overall trends are valid as observed for the students, *Figure 2* and *Figure 4*. At both universities the instructors found that the TMs least supported "the students own time management". At UT the instructors found that the criteria best supported by ALEx were "support multiple ways of learning" (4.0±0.8) and "support prompt feedback" (4.0±0.8). For NTU Singapore the best rated criteria were "support collaboration among students" (4.4±0.5) and "support responsibility for own learning" (4.4±0.5). The largest difference in mean scores (1.2) is observed for the criterion "support well-structured and organized teaching" in favor of TBL (*Figure 4*).

Discussion

The aim of this study was to identify criteria for good teaching of large classes and compare these criteria up against features of two recently proposed innovative TMs, ALEx and TBL. It is clear that some criteria such as communicating high expectations to the students, sharing your love for the curriculum with the students and focusing on key concepts are universal teaching criteria and not exclusively valid for large class teaching. For this reason, only those criteria we deemed directly influenced by the class size were selected. It is therefore important to realize that the 7 identified criteria for good teaching of large classes cannot stand alone and that there might be criteria which we have failed to identify.

Overall, the criteria for good large class teaching identified in this study were consider to be important to very important by both students and instructors, *Figure 1* and *Figure 3*. The only two criteria on average scoring below 3 (on a scale from 1 to 5) are "student-faculty contact outside class" and "clearly define how much time students should spend on specific tasks" for teachers and TAs at UT. In general, the criteria identified are considered more important at NTU Singapore compared to UT, *Figure 1* and *Figure 3*.

When it comes to how well TBL and ALEx support the identified criteria, TBL are consistently scoring higher average grades, *Figure 2* and *Figure 4*. Despite this, we cannot conclude that TBL, in general, is superior to ALEx as there are factors, which we have not taken into account. Firstly, there are differences in the two student populations. The TBL taught at NTU Singapore is primarily done for Asian male students in the age 20-21 years old - 25% female students of 19 years old. For ALEx at UT the students represented a much more multicultural society, with an almost equal gender distribution. The majority of the students at UT were in the age of 18-19 years old. The students following the REP at NTU are premier academic scholars and are among the top scorers in the Singaporean national cohort. There might be other cultural differences, which we have not considered. Secondly, there are differences introduced with the instructors conducting the teaching. Thirdly, there might also be context specific issues, which we have not been able to take into account in this study. For instance, at UT they had just completed a new lecture hall with new equipment and new possibilities, which they used for the first time. This might have influenced the performance of ALEx. Thirdly, the class size at UT is more than 10 times larger than the TBL class at NTU, 60 students vs. 850 students, respectively, which makes collaboration, student-faculty contact and especially providing feedback to the students much more difficult. The class size difference are most likely the most important factor influencing the students' evaluation of the TMs. Also, the student and faculty response rates for UT are very low, which makes the interpretation problematic. Lastly, this study have not considered the actual learning of the students.

To validate our findings, would be advisable to perform a study on one group of students, with only one team of instructors teaching with various TMs. Also, it would be interesting to see how the teaching facilities influence the outcome of the various TMs.

Instructors and TAs were asked to assess the feasibility of their respective TM, by evaluating the demand for technical and instructor resources allocated and the flexibility of the TMs when it comes to teaching facilities. None of the TMs score high average grades for any of these criteria, *Figure 4*, reflecting that ALEx is heavily instructor dependent and needs implementation of a LMS and that TBL, optimally, requires specialize lecture rooms facilitating in class plenum discussion where the students can sit in teams.

When considering the findings of this study it is important to recognize that there are no universally accepted criteria for what constitutes good teaching, and that good teaching always should be seen in a greater context and that it is student and teacher dependent [3], [26]. Also, the study suffered from a low response rate at UT (6% for students and 8% for instructors), making the confidence intervals broad. Despite this, we identified some important criteria for large class teaching, which teachers and instructors can use as to measure of their teaching performance and as a checklist. Also, TBL consistently scored higher when it comes to facilitation of the identified criteria, indicating a high potential for large class teaching.

The two teaching methods evaluated in this study were selected as they have both been proposed in the literature and holds the potential to be implemented on a large scale in a university teaching setting [5], [6]. Other TMs e.g. problem-based learning or case-based learning and other, would also be worth considering for future studies and there might be variations of the two TMs assessed in this study, which addresses their potential weaknesses.

Conclusions

In this study seven criteria for what constitutes good practice within large class teaching were identified by a literature review. Additionally, three criteria were added considering the feasibility of large class teaching. Two teaching methods, TBL and ALEx, were selected and

evaluated against the criteria identified for good large class teaching by surveying students and instructors at NTU Singapore and UT.

We conclude that the criteria identified are, by students and instructors, considered to be important to very important – 4 to 5 on a scale from 1 to 5. TBL performs markedly better than ALEx in this study when it comes to facilitation of the identified criteria, but we stress that a direct comparison is difficult as teacher, course topic, students, cultural settings and context specific issues are not comparable. However, the identified can be seen as a checklist for instructors of large classes and as a method to evaluate their teaching performance.

In order to validate and further explore the findings of this study, a study should be completed on a single group of students being taught the same course topic by a single group of teachers using different types of TMs.

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